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13. ABSTRACT *(Maximum 200 words)*

The purpose of this research was to pursue further understanding of cloud electrification through three separate projects. First, radar observational data of New Mexico thunderstorm activity combined with a numerical thunderstorm model suggests that the degree of thunderstorm electrification depends on the time during which strong updrafts remain within the charging zone. Second, a simple numerical lightning model representing streamer propogation on a 2-D grid was developed. Realistic streamer paths evolve in the model and the conditions for IC and CG strokes are directly related to updraft velocity. Third, a simple cloud model was utilized to investigate factors influenceing lightning frequency and its relationship to precipitation. Lightning and lightining frequencey are shown to heavily depend on the depth of the charging region which is sensitive to vertical velocity.

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January 4, 1994

Final Report: AFOSR Grant AFOSR-91-0012 (Lightning Initiation II)

P.I. M. B. Baker

Under this grant we worked on three major projects, as follows.

1. Electrification of New Mexico Thunderstorms

We examined a series of summer thunderstorms in New Mexico to determine which characteristics of the clouds, all of which formed in similar soundings, determined their eventual electrical characteristics. To this end we examined radar and aircraft data and used our numerical thunderstorm model (Norville et al, 1991) to attempt to determine the dominant factors required for electrification. Our studies suggest that electrification depends strongly on τ_{cz}, the time during which updraft velocities in the charging zone remain high. We also examined the correlations between lightning predictors (CAPE, cloudtop height, lifted index and wet bulb potential temperature at the ground) and observed lightning. We find that CAPE is the most successful predictor for these storms, and we suggest that this is because CAPE is highly correlated with τ_{cz}. This work (Solomon and Baker, 1994) has been accepted for publication in Monthly Weather Review.

2. A Simple Numerical Lightning Model

We have derived a unique, physically reasonable model of streamer propagation on a 2-D grid. In the model we specify initial charge density as a function of position and compute the electric field everywhere. The conditions for breakdown are defined in terms of electric field intensity and proximity of previous breakdown locations. If breakdown occurs at a grid point, the motion of charges in its environment is simulated by placing dipoles on the neighboring grid points accroding to a specified recipe. Charge transfer by hydrometeor collisions is represented as a simple function of position and its effects are computed over each time step. The macroscopic motions of hydrometeors are represented by simple, time-independent one-dimensional fall and updraft velocities. The field is then recomputed and the process is repeated. Realistic streamer paths evolve in the model and the conditions for C-G and I-C strokes are expressed as simple functions of the updraft velocity, the spatial extent of the grid and the charge transfer rate. This work was presented as a poster at the San Francisco AGU meeting and is now being written up for publication (Norville, 1993).

3. A One-Dimensional Model of Lightning from Convective Clouds

We have derived a very simple cloud model and representation of lightning strokes to investigate the factors determining lightning frequency and its relationship to precipitation. In the model the ice crystal populations are considered independent of time, as is the updraft velocity. Glaciation occurs either via the Hallett-Mossop process or via temperature dependent nucleation according to the Fletcher parameterization, and we find that electrification depends to some extent on the glaciation process. All charge transfer occurs via ice crystal-hail collisions, and the hail particle sizes are determined from the prescribed liquid water content in the cylindrical cloud. Breakdown occurs whenever the electric field reaches a threshold value, and we assume at present that when breakdown occurs a streamer propagates from the breakdown location in the direction of minimum local field gradient, to the ground if that minimum gradient is below the breakdown point and otherwise to the anvil.

During lightning a fixed fraction of the charge in the anvil is moved, either from the ground to the breakdown point or from the anvil to that point. This model, which is still under development, shows that lightning and lightning frequency depend very strongly on the depth of the charging region, which is a sensitive function of vertical velocity. We have derived a charging parameter, a function of radar reflectivity and ice crystal mass at the balance level and the cloud radius, and we show that over a wide range of atmospherically relevant conditions lightning will occur only when this parameter has a value above unity. This work was presented at the AGU meeting in San Francisco and is now being written up for publication. (Baker et al, 1993).

References:

Baker, M., H. Christian and J. Latham (1993) Proceedings, AGU Fall Meeting, p. 153.

Norville, K., M. Baker and J. Latham (1991) J. Geophys. Res. 96, 7463-7481.

Norville, K. (1993) Proceedings, AGU Fall Meeting, p. 155

Solomon, R. and M. Baker (1994) to be published, Monthly Weather Review.